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Comparison of different scoring systems for predicting mortality and morbidity after neonatal heart surgery

Mortality and morbidity in newborns

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Abstract
Aim: In this study, it was aimed to evaluate the effect of neonatal intensive care scoring systems and surgical-related scoring systems, which were used after congenital heart surgery, on predicting mortality and morbidity in newborns.
Material and Methods: This study was carried out on patients who underwent neonatal cardiac surgery and were followed in the pediatric cardiac intensive care unit between July 1, 2021 and July 1, 2022. Thoracic Surgeons and European Association for Cardiothoracic Surgery mortality categories (STS-EACTS MC) STAT score, Vasoactive inotrope score (VIS) and Vasoactive Ventilation Renal (VVR) scores in the first 48 hours of newborns who were admitted to the intensive care unit after the cardiac surgery were calculated. The effects of these results on hospital morbidity (long stay in intensive care unit=longer than the upper 25th percentile of total stay) and hospital mortality (developing before the first 30 days after surgery) were investigated. The results were evaluated statistically.
Results: One hundred and sixty cases (50% male) were included in the study. The median age was 7 days (IQR 3 -10 days); 30 percent had single ventricular physiology. The duration of intensive care stay was >216 hours and the total mortality was 12.5% (n=20). A STAT ≥ 4 score was a strong predictor of both long intensive care stay (OR 2.1) (CI 95% 1.3-3.4 P=0.04) and hospital mortality (OR 4.2) (CI 95% 2.2-9) P = 0.008).
The maximum 48th-hour VVR score was a strong predictor of both long intensive care stay (OR 1.8;(CI 95% 1.3-2.2 P=0.001)) and hospital mortality (OR 1.56;(CI 95% 1.3-2.9)).
Discussion: STAT and VVR scores can help to predict mortality and morbidity in newborns after cardiac surgery.

Keywords
Newborn, Congenital Heart Surgery, Scoring Systems

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Introduction

Congenital heart diseases (CHD) are the most common cause of acute heart failure in newborns and may result in low cardiac output after birth. Due to the wide spectrum of CHD, patients might have different pathophysiological clinical conditions. Depending on the type of CHD, some patients can be discharged home, but some may require follow-up in the intensive care unit. Approximately 25% of the cases underwent either interventional treatment (angiography or surgical) within the first year of life [1].

Various scoring systems are used to evaluate the morbidity and mortality results after congenital heart surgery [2-3]. In general, the basic features required in these scoring systems are as follows: easy data entry, creation of a common and reliable database, reduction in the cost of intensive care units, efficient use of resources, the guidance of clinical decisions and applications and provision of objective evaluation. However, the issue of which scoring system is the best is still controversial.

Although RACHS-1 (Risk Adjustment in Congenital Heart Surgery), Aristotle Basic Complexity Score (ABC), Aristotle Comprehensive Complexity Score (ACC) and Thoracic Surgeons and European Association for Cardiothoracic Surgery mortality categories (STS-EACTS MC) STAT scores are frequently used as a scoring system, they are mostly based on the difficulty of surgical operation, and they don't contain enough data about the clinical outcome of the intensive care follow-up [4-5]. In some studies, it has been suggested that the STAT score is the most successful scoring system for predicting mortality and morbidity among these four systems [5-6].

Lactate and vasoactive-inotropic score (VIS) were frequently used to evaluate the clinical status and outcome in pediatric cardiac intensive care, but they can modestly predict the outcome [7]. Recently, for the postoperative period, it is suggested that the vasoactive-ventilation-renal (VVR) score can be used as a strong marker [8].

There are limited studies on the use of these different scoring systems during newborn period. In this study, we investigated the efficiency of STAT score and VVR scores, for predicting hospital mortality and morbidity, in different types of newborn CHD patients.

Material and Methods

This study was conducted, between 1 July 2021 and 1 July 2022, on patients who underwent neonatal heart surgery operation and were followed up in the pediatric cardiac intensive care unit. Patients requiring ECMO support, premature newborns, permanent pacemaker implantation patients and patients transferred to a different unit within the first 72 hours after the surgery were excluded from the study. This retrospective study was approved by the institutional ethics committee and was conducted in accordance with the principles of the Declaration of Helsinki.

The preoperative demographic data (gender, weight, and additional genetic syndromes), anatomical diagnosis, surgical data, clinical follow-up, and postoperative intensive care unit reports of the study group were evaluated.

Thoracic Surgeons and European Association for Cardiothoracic Surgery mortality categories (STAT) were applied according to the analysis reported in the literature. The mortality risk was estimated for 148 procedure types, using real data from 77,294 patients (33,360 patients from the EACTS and 43,934 patients from the STS) between 2002 and 2007. Using Bayesian statistics that fit the data for small denominators, mortality rates were calculated for each procedure. For the STAT, the scale ranged from 0.1 to 5.0, and a corresponding mortality category level between 1 and 5 was assigned (level 1, 0.1-0.3; level 2, 0.4-0.7; level 3, 0.8-1.2; level 4, 1.3-2.6; level 5, 2.9-5.0) [9].

Urea and creatinine values were retrospectively collected from the hospital database from biochemical blood values, which are routinely gathered preoperatively, at postoperatively 24 hours and 48 hours. Acute kidney injury (AKI) was classified using the AKI network staging system.

Postoperative data of arterial blood gas parameters including PH, partial pressure of carbon dioxide (PaCO2), and partial pressure of oxygen (PaO2) at admission in PICU, 24 h, and 48 h postoperatively along with the corresponding ventilator settings, including peak inspiratory pressure (PIP), positive end-expiratory pressure (PEEP), mean airway pressure, and respiratory rate (RR) in the volume-controlled mode of ventilation were collected.

Doses of inotropic and vasopressor agents were also recorded at the time of each blood gas analysis. Postoperative serum creatinine was recorded at admission, 24 h, and 48 h postoperatively.

VIS and VVR scores were calculated for all patients at the study time point. VIS was calculated using formulae; VIS = Dopamine dose (μg/kg/min) + Dobutamine dose (μg/kg/min) +100 × Epinephrine dose (μg/kg/min) +10 × Milrinone dose (μg/kg/min) +10000 × Vasopressin dose (μg/kg/min) +100 × Norepinephrine dose (μg/kg/min) [7]. Ventilation index (VI) was calculated using the formula: VI = RR × (PIP−PEEP) × PaCO2/1000; Δ Cr was calculated by subtracting serum creatinine (in mg/dl) at the time of each measurement with preoperative serum creatinine and VVR using the formula: VVR = VIS + VI + (Δ Cr × 10) [8]. For patients whose postoperative serum creatinine values were less than preoperative values, Δ Cr was taken as 0. For patients not requiring ventilator support at the time of measurement, VI was taken as 0.

In this study, our two primary outcomes were operative mortality and Pediatric Cardiac Intensive Care Unit Length of Stay (PCILOS). Operative mortality included all the deaths that occurred during the hospital stay when the operation was performed, and the deaths occurred after discharge within 30 days of the procedure. For further analysis of PCILOS, data were dichotomized as the upper (worst) 25th percentile versus lower (best) 75th percentile. PCILOS in the upper 25th percentile was considered a prolonged Pediatric cardiac intensive care unit length of stay.

In each scoring system, a higher score indicates a higher risk of mortality. For patients undergoing multiple procedures, the procedure with the highest level was scored. The scores of each patient were calculated according to the STAT, VIS and VVR scoring systems and recorded.

Statistical analysis

Data were analyzed using SPSS (Statistical Package for Social

Sciences) statistical software, version 15 for Windows. Median with range was used to describe continuous data whereas absolute count with percentage was used for categorical data. Data were analyzed for correlation between the scores and outcome using Spearman's rho.

Univariate analysis was performed for demographic and clinical characteristics of patients to predict our two primary outcomes using the Mann–Whitney U-test, Chi-square test, or Fisher's exact test as appropriate for individual variables. Significance variables were included in the multivariate logistic regression model, and the odds ratio (OR) was calculated. P < 0.05 was considered significant. Analysis of the discriminatory ability of the risk stratification methods was per¬formed using the C statistic comparison with the ROC curves of the two methods.

Results

There were 160 cases (50% male) during the study period. The median age was 7 days (IQR 3-10 days) and the median weight was 3 kg (IQR 2,8 – 3,2 kg). The most common diagnoses of the cases were aortic arc hypoplasia (n=40), transposition of the great arteries (n=35), Hypoplastic left heart syndrome (n=25), and total abnormal pulmonary venous return anomaly (n=20). Single ventricle physiology was seen the 30% of the cases, and 130 of them (80%) were STAT≥4. The main characteristics of the cases are shown in Table 1.

The median ICU stay was 7 days (IQR 5- 9 days). Prolonged intensive care stay (PICS) was observed in 45 cases and mortality in 20 cases. The length of PICS was > 216 hours and total mortality was 12,5% (n=20).

Table 1. Demographics and patient characteristics

Variables	Median (IQR) or n%
n	160
Age (days)	7 (3-10)
Weight (kg)	3 (2.8-3.2)
Body surface area (m2)	0.20 (0.18-0.22)
Male	80 (50)
STAT category	
1-2-3	16 (10)
4	93 (58)
5	51 (32)
Syndrome	8 (5)
Cardiopulmonary bypass	144 (90)
Emergent procedure	64 (40)
Physiology	
Single ventricle	48 (30)
Biventricular	132 (70)

The median VIS was 10 (IQR 8-12) and the median VVR score was 40 (IQR 35-45) at hour 0. The median VIS was 7 (IQR 5-10) and the median VVR score was 30 (IQR 25-35) at the 24th hour. The median VIS was 5 (IQR 3-7) and the median VVR score was 16 (IQR 14-18) at the 48th hour. The VVR score was higher at each measurement point compared to the corresponding VIS. According to correlation analysis, VVR score predicted endpoints better than VIS at each measurement point. In particular, VVR 0.hour PICS c index= 0.76(CI:0.72-0.80), mortality c index= 0.80(CI: 0.76-0.85). VVR 24th hour PICS c index= 0.78(CI:0.74-0.82), mortality c index= 0.83(CI: 0.80-0.86). VVR 48th hour PICS c index= 0.87(CI:0.82-0.92), mortality c index= 0.82(CI: 0.80-0.84). Maximum 48th hour VVR score PICS c index = 0.88 (CI: 0.86-0.90), mortality c index = 0.92 (CI: 0.90-0.93). The maximum 48th-hour VVR score was the most powerful of all to show mortality (0.92) and morbidity (0.88) (Table 2).

The evaluation results of the factors affecting the prolonged intensive care unit stay are shown in Table 3. When multivariate regression analysis of factors with p< 0.05 was performed, the following factors were found to independently increase the risk; STAT score ≥ 4 OR 2.1(CI %95 1.3-3.4 P=0.04), AKI> 2 OR 1.1(CI %95 1-2.2) P = 0.04), presence of postoperative arrhythmia OR 4.5(CI %95 2.4-6.6 P=0.001), the maximum VVR score OR 1.8;(CI % 95 1.3-2.2 P=0.001) and VVR score OR 1.44;(CI1.2-1.6 P=0.001).

The evaluation results of the factors affecting mortality are shown in Table 3. When multivariate regression analysis of factors with p< 0.05 was performed, STAT score ≥ 4 OR 4.2 (CI %95 2.2-9) P = 0.008) AKI> 2 OR 3.1(CI %95 1-9) P = 0.02), the maximum VVR score OR 1.56;(CI % 95 1.3-2.9), P=0.001) and the 48th-hour VVR score OR 1.30 (CI %95 1.2-1.5), P = 0.001) were found to be independent risk factors.

Table 3. Factors affecting prolonged intensive care unit stay and mortality

Variables	pCILOS (+) n=45	pCILOS (-) n=115	p	Mortality (+) n=20	Mortality (-) n=140	p
Age/days	3 (4-6)	5 (3-8)	NS	3 (4-6)	5 (3-8)	NS
Sex/male	20 (44)	60 (52)	NS	10 (50)	70 (50)	NS
Syndrome	5 (11)	3 (2.5)	NS	3 (15)	5 (3.5)	NS
STAT≥4	45 (100)	99 (86)	0.03	20 (100)	124 (88)	0.04
AKI≥2	20 (44)	18 (15)	0.001	18 (90)	20 (14)	0.01
Arrhytmia	11 (25)	10 (11)	0.008	13 (65)	8 (5.7)	0.01
VVR 48-hour	30 (24-36)	18 (14-22)	0.001	35 (30-40)	25 (21-29)	0.001
VVR 48-hour max	36 (30-40)	21 (16-26)	0.001	42 (36-48)	25 (21-30)	0.001

Median (IQR) or n(%) AKI: Acute kidney injury; STAT: European Association for Cardio-Thoracic Surgery, pCILOS: pediatric cardiac intensive care unit length of stay, VVR: Vasoactive-ventilation-renal

Table 2. Results regarding area under the ROC curve between the methods concerning the mortality and PCILOS outcomes

VVR score	Mortality*			PCILOS&		
	Spearman	Area under ROC curve	CI 95%	Spearman	Area under ROC curve	CI 95%
Admission	0.16	0,8	0,76- 0,85	0.42	0,76	0,72- 0,80
24-hour	0.24	0,83	0,80-0,86	0.55	0,78	0,74- 0,82
48-hour	0.43	0,82	0,80-0,84	0.70	0,87	0,82-0,92
48-hour max	0.70	0,92	0,90-0,93	0.75	0,88	0,86-0,90

* No significant difference was found between 24 and 48 h VVR (P > 0.05) in predicting mortality, whereas both 24 (< 0.05), 48 h VVR (P =0.001) and maximum 48-h VVR (p=0.001) were significantly better than 0 h VVR. There was no difference between the groups when the groups are compared with each other (p>0,05)

VVR score at 48 hours was further dichotomized in high and low to simplify its interpretation. When the PICS duration cut-off was taken as 25, the sensitivity and specificity of the maximum 48th-hour VVR score were 80% and 75%, respectively. And when the hospital mortality cut-off was taken as 40, the sensitivity and the specificity of the maximum 48th-hour VVR score were 93% and 86%, respectively.

Discussion

In this study, the power of different scoring systems to predict morbidity and mortality in newborns undergoing congenital heart surgery was investigated. We found that high STAT and VVR scores strongly predict mortality and morbidity and with these aspects this study is one of the limited studies in the literature.

The scoring systems are needed for the comparison and analysis of mortality and morbidity of congenital heart diseases due to the large number and complexity of the surgical operations. RACHS-1, ABC, ACC and STAT mortality scores are used for classification according to these surgical features. Risk Adjustment in Congenital Heart Surgery has been the first system used for this purpose. It is rather an easier model, because it needs less data. Although it does not contain all cardiac procedures and is based on personal foresight, it is widely used to determine mortality. The European Association for Cardiothoracic Surgery defined the Aristotle scoring system as two separate scoring systems, namely, ABC and ACC, in 2014. The first score was the Basic score, which adjusted only for the complexity of the procedure. The second score was the Comprehensive score, which took into account specific procedure-dependent and procedure independent patient characteristics. It is divided into four levels according to difficulty. Society of Thoracic Surgeons and the European Association for Cardiothoracic Surgery mortality categories (STAT) is the most recent scoring system estimating mortality based on processing data from a database containing 148 different procedures. It is divided into five subgroups according to difficulty level [4,6]. STAT is the most recent of these scores and its effectiveness has been demonstrated in different studies. In the series of Yıldız et al [6] with 1950 cases and O'Brien [9], it was stated that the best surgical scoring system was STAT. We evaluated the STAT system in our study. In our newborn series, STAT score ≥ 4 predicted mortality and morbidity as an independent risk factor.

Recently, it has been stated that the scoring systems used after the operation will not be sufficient alone, and the evaluation of all body systems along with it would be useful. Miletic et al. [8] were the first who introduced the VVR scoring system, which enables the evaluation of heart, lung and kidney functions together. In their study of 222 cases younger than 365 days who underwent surgery for congenital heart disease and without residual mixing lesion or single ventricle physiology, they suggested that the VVR score is a powerful method for evaluating cardiac surgery outcomes.

The most important advantage of the VVR score compared to other indices is that it includes patients who are hemodynamically stable and do not need much support, but who have postoperative lung and kidney damage. Making these calculations with routine laboratory data in clinical practice and a simple calculation at the bedside makes it easier to use. However, the main problems for widespread clinical use in a heterogeneous disease group such as congenital heart diseases are the uncertainties about which age group, at what time postoperatively, and what the cutoff values should be. With more studies to be done in the future, the patient's age group and disease-specific cut-off values will be determined [8,10,11]. Öztürk et al. [10] suggested that the 48th hour VVR score could predict mortality and morbidity as an independent risk factor in their series of 340 cases. Zubarioğlu et al. [11] in their study of neonatal cardiac surgery cases stated that the VVR score in the maximum first 72 hours was a strong marker in determining intensive care and hospital mortality.

In our study, a maximum 48th-hour VVR cut-off value of >25 was found associated with prolonged intensive care unit time and a cut-off value of >40 VVR was found associated with mortality.

Alam et al. [12] compared the power of VVR and VIS values in predicting clinical outcomes in their study and found that VVR had a significantly better prediction at all times. In their study of 164 cases, Sherer reported that VVR predicted prolonged ICU duration better than lactate and VIS values in the early postoperative period [3]. Findings were similar in the study by Öztürk et al [10]. In our study, the relationship between VVR and VIS was in parallel with the studies above. This shows the direct contribution of respiratory and renal parameters to postoperative outcomes in newborn cases.

In our study, other factors affecting mortality and morbidity were also evaluated independently from the VVR score. Arrhythmia and AKI > 2 were found to be other effective factors of morbidity and mortality. These results were similar to previously reported studies [12-14].

Limitation

The main limitation of the study is its retrospective nature with a limited number of cases from a single center. The heterogeneity of the cases is another limitation.

Conclusion

We validated the utility of the STAT and VVR scores in neonatal cardiac surgery for critical congenital heart disease. STAT and VVR scores can help predict mortality and morbidity in newborns after cardiac surgery. There is a need for studies with a larger number of patients on this subject.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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